



The Nature and Nurture of Addiction

According to J.D. Rolleston, a British medical historian, a medieval Russian cure for drunkenness consisted in "taking a piece of pork, putting it secretly in a Jew's bed for nine days, and then giving it to the drunkard in a pulverized form, who will turn away from drinking as a Jew would from pork." [Quoted in Roueche, op. cit. p. 144]

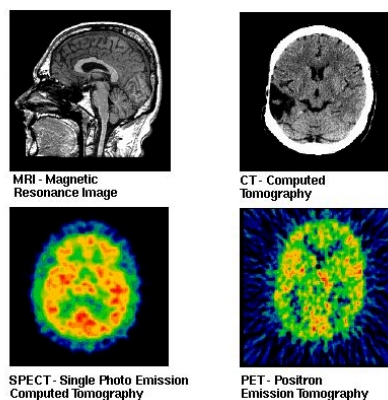
Treatment of addiction in times past has included such things as sterilization, enemas, electric shock, forced drunkenness, public humiliation, flogging, and other bizarre if not sad attempts to address a problem that has tortured mankind for thousands of year.

Introduction

Old medical texts sometimes make us laugh, and sometimes make us cry. Addictions have been with humans for thousands of years, and there have been about as many ideas about the causes of addiction. "Nothing," said one sage, "is as useful as a good theory."

About 10 years ago, the scientific study of the brain changed with the introduction of machines capable of studying the living brain. The first commercial scanner was sold in 1989, and the science of brain and behavior as not been the same since. Many different types of scanners exist, as shown in the Figure 2.

Figure 3: Different Types of Brain Scans



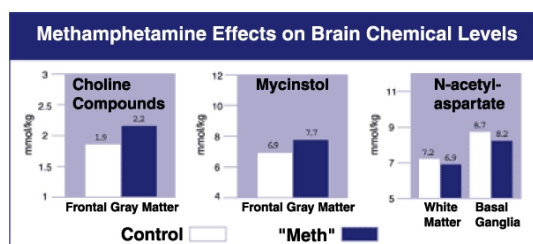
The language of addiction has historically been filled with pejorative language about the people who are addicted, with little sympathy for their plight or addiction. Less than 50 years ago the same was true for mental illness. Theories of mental illness 50 years ago were potentially more toxic than the disorders in creating human suffering.

The Nature and Nurture of Addiction

Understanding of the changes in the human brain for bipolar disorder and schizophrenia have allowed for huge advances in the treatment both by behavioral medicine and pharmacology.

The research on brain mechanisms is dramatically advancing our understanding of addiction. The same is true for the expanding research on neurotransmitters and the action of substances or activities associated with addiction: alcohol, tobacco, other drugs, food, sex, and gambling. A recent study supported by the National Institute on Drug Abuse illustrates the relationship between drugs (methamphetamine), brain structures and brain chemistry.¹

Figure 4: Research on Meth Effects



We know much more today about the “how” of addiction. The recent discoveries go beyond brains, behavior,

and chemicals. The discoveries also go to human genes and how they predispose individuals to addiction. Other scientific advances, particularly in evolutionary psychology, give us understanding of “why” addictions happen.

The request for a comprehensive report to the Wyoming Legislature and citizens must include an overview of scientific understanding, as a foundation for effective treatment, intervention, prevention and control. This report only touches the surface of the science of addictions, and new discoveries will change some of the current ideas and give us a greater chance for achieving the vision of this report.

A note of caution needs to be remembered. Science is mankind’s humble attempt to understand the world. It is a process. Scientists are prone to the same foibles as any human. The very process of science, since it is dedicated to the pursuit of truth, ferrets out poor logic, bad theory, corrupt data, and sloppy methods over time. What follows is a summary of key ideas of today.

Mapping the Brain and Addiction

The technology briefly described earlier makes it possible for us to understand that the seat of addiction is not in the drug but in the brain. The brain controls behavior and both events and drugs change the brain.

What follows below are a few brain scans, using different technology. Each shows the impact of different drugs on the human brain. The scans provide a visual foundation for the text that follows.

The Nature and Nurture of Addiction

Figure 5: Various Brain Scans



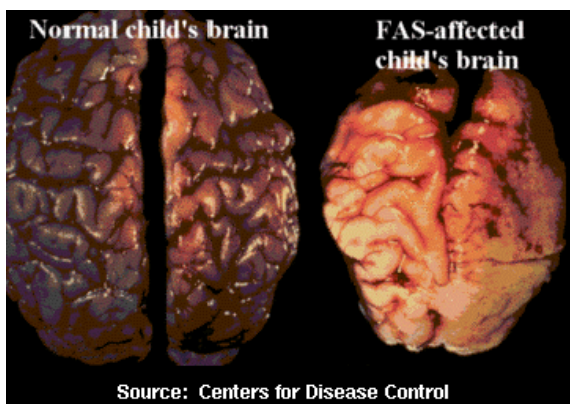
Control



Alcoholic

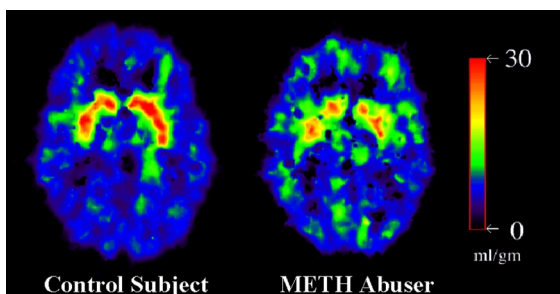
Magnetic Resonance Scan

The MRI scan here shows the impact of long-term alcoholism on the adult human brain. Considerable loss of pre-frontal capability (planning, goal setting, etc.) has happened. This is the loss of “will power” and intelligence in lay terms. This scan is important to Wyoming because our youth are likely to have earlier binge drinking, which predicts long-term alcoholism.



Forensic Brain Sample

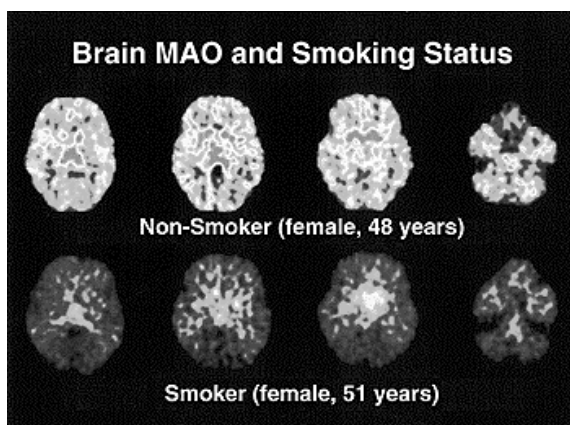
Autopsies enable researchers to examine the actual brains and other organs of individuals. Here, one can see the brains compared of two children of the approximate same age who happened to die from accidental causes. One brain is of a normal child; the other brain is that of a child who was affected by fetal alcohol syndrome (FAS). Again, these data are important to Wyoming, because we have 2-3 times the national rate of serious alcohol, tobacco, and other drug consumption in our state by pregnant women.



PET Scan of Methamphetamine Use

Two studies by researchers at the U.S. Department of Energy's Brookhaven National Laboratory provide evidence that abuse of methamphetamine changes physiology in the brain. Here, 80 days after detox, a meth user still shows a major reduction of dopamine transporter, resulting in poor cognitive and motor function. This reduction lasts for as long as 11 months, and bodes poorly for Wyoming, where meth use is substantially above the national average.

The Nature and Nurture of Addiction



Scan and Tobacco Use

In this scan, the brain of a smoker is working less actively than the brain of a matched non-smoker, as measured by monoamine oxidase.² Scientists believe that these differences help explain the long-term cognitive deficits that emerge among long-time users of tobacco. Over time, smoking reduces the cognitive ability of adults, making them less productive, a fact unknown even a decade ago. Smoking also leads to increased job instability. Again, these medical data are worrisome for us because of the high rates tobacco use by our young people and adults.

REPRINT: Addiction: ‘Oops,’ a brain disease with clear biological underpinnings

By Doug Toft

This article originally appeared in the Winter 2001 issue of the Hazelden Voice Newsletter. Permission to copy and reprint is granted by the Hazelden Foundation.

No one raises a glass of alcohol, snorts a line of cocaine, or lights up a nicotine-laden cigarette with a toast: “Here’s to addiction.” When first using these drugs, people simply choose to do something that makes them feel good. But with continued use, these people can find themselves addicted: They depend on the drug not simply to feel good but to feel *normal*. Using drugs is no longer a choice but a compulsion. These people don’t plan to become addicts; it just happens.

In a recent article, Alan Leshner, PhD, director of the National Institute on Drug Abuse, calls this the “oops phenomenon.” It happens when occasional use of a drug turns into weekly use, then daily use, and then eventually into a surprising, distressing realization: “I’m addicted.”

“Every drug user starts out as an occasional user, and that initial use is a voluntary and controllable decision,” Leshner writes. “But as time passes and drug use continues, a person goes from being a voluntary to a compulsive drug user. This change occurs because over time, use of addictive drugs changes the brain—at times in big dramatic toxic ways, at others in more subtle ways, but always in destructive ways that can result in compulsive and even uncontrollable drug use.”³

The fact is, drug addiction is a *brain disease*, Leshner says. “While every type of drug of abuse has its own individual trigger for affecting or transforming the brain, many of the results of the transformation are strikingly similar regardless of the addictive drug used. The brain changes range from

The Nature and Nurture of Addiction

fundamental and long-lasting changes in the biochemical makeup of the brain, to mood changes, to changes in memory processes and motor skills.”

The changes Leshner refers to include specific alterations in the structure and function of the brain. Thanks to recent advances in research, we have a much more complete picture of those changes. With these discoveries have come new insights into the role of heredity—findings that may actually identify people at risk for addiction and prompt them to learn behaviors that prevent the disease.

Drugs change brain structure

Begin with structural changes in the human brain. Long-term drinking literally shrinks this vital organ. Autopsies consistently show that chronic alcoholics have lighter and smaller brains than other people of the same age and gender. Researchers have also observed this shrinking effect in living alcoholics through non-invasive medical tests that give a picture of the brain in action. These tests include magnetic resonance imaging (MRI), positron emission tomography (PET) scans, and computed tomography (CT) scans.⁴

The same techniques reveal how addiction harms or even kills brain cells. For example, research indicates that methamphetamine (“speed”) damages cells that produce dopamine, a chemical in the brain that helps to create feelings of euphoria. Methamphetamine use can even trigger a process called apoptosis, where cells in the brain self-destruct.

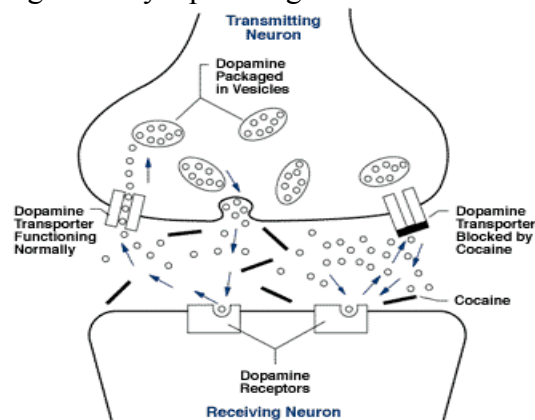
In long-term alcoholics, such changes can be devastating. Studies indicate that 50 to 75 percent of these drinkers show some kind of cognitive impairment, even after they detoxify and abstain from alcohol. According to the National Institute on Alcohol Abuse and Alcoholism, alcoholic dementia is the second-leading cause of adult dementia in the United States, exceeded only by Alzheimer’s disease.⁵

Drugs change brain function

The effects of addiction on the brain don’t stop with brain size. Research over the last decade reveals that addictive drugs also alter the function of the brain—the very way that cells work.

Human beings are “wired” with nerve cells (neurons) that extend from the brain and spinal cord throughout the body. Neurons with the same function group themselves into strands up to four feet long. However, the strands are not continuous. Between neurons is a small space called a *synapse*.

Figure 6: Synapse Diagram



The Nature and Nurture of Addiction

Researchers used to think that neurons passed signals to each other by sending electrical impulses across synapses—something like the way that electricity jumps the gaps in a car's spark plugs. Today we know that what crosses the synapse are not “sparks” but chemicals. Those chemicals are called *neurotransmitters*. The constant exchange of neurotransmitters makes it possible for the brain to send messages through vast chains of neurons and direct our thoughts, feelings, and behavior.

Addictive drugs wreak havoc with this normal exchange of neurotransmitters in countless ways. For example, drugs can:

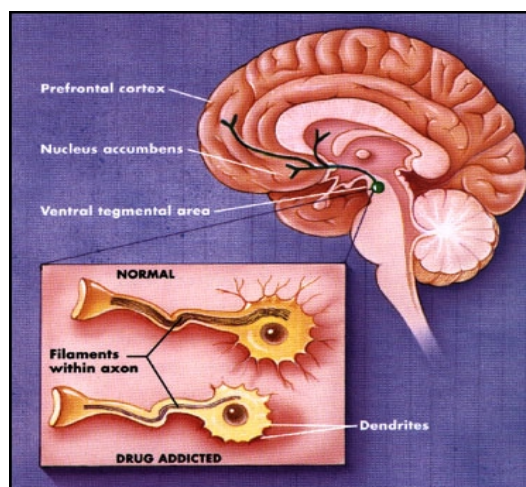
- ⇒ Flood the brain with excess neurotransmitters.
- ⇒ Stop the brain from making neurotransmitters.
- ⇒ Bind to receptors in place of neurotransmitters.
- ⇒ Block neurotransmitters from entering or leaving neurons.
- ⇒ Empty neurotransmitters from parts of the cells where they're normally stored, causing the neurotransmitters to be destroyed.
- ⇒ Increase the number of receptors for certain neurotransmitters.
- ⇒ Make some receptors more sensitive to certain neurotransmitters.
- ⇒ Make other receptors less sensitive to neurotransmitters (leading to tolerance).

- ⇒ Interfere with the reuptake system by preventing neurotransmitters from returning to the sending neuron.

A case in point—dopamine

Dopamine, mentioned above, is one of the primary neurotransmitters involved in addiction. All the major drugs of abuse—alcohol, nicotine, opiates, and cocaine—increase dopamine levels. That's a “good news-bad news” scenario. The “good” news, at least temporarily, is that the excess dopamine creates powerful feelings of pleasure. The bad news is that the excess levels take a long-term toll on brain chemistry and promote addiction.

Figure 7: Brain Changes From Drug Abuse



To understand this, remember the biological concept of *homeostasis*, a word that literally means “same state.” The brain seeks to maintain a constant level of cell activity. That stable level is critical to regulating our behavior. When supplies of dopamine remain constant,

The Nature and Nurture of Addiction

we can experience the ordinary pleasures of life — such as eating and having sex — without the compulsion to seek those pleasures in self-destructive ways.

When consistently subjected to artificially high levels of dopamine from use of a drug, however, the brain “downshifts” its internal supply of this neurotransmitter. The brain comes to depend on the presence of a drug in order to maintain homeostasis and function normally.

And that’s the problem. If the extra dopamine supplied by drugs is missing, the alcoholic or drug addict feels much less pleasure. In fact, these people can experience symptoms such as depression, fatigue and withdrawal. To the addict, it seems that the only relief from these symptoms is to use more and more drugs. It all adds up to craving—addicts’ constant drive to obtain their chemicals of choice.

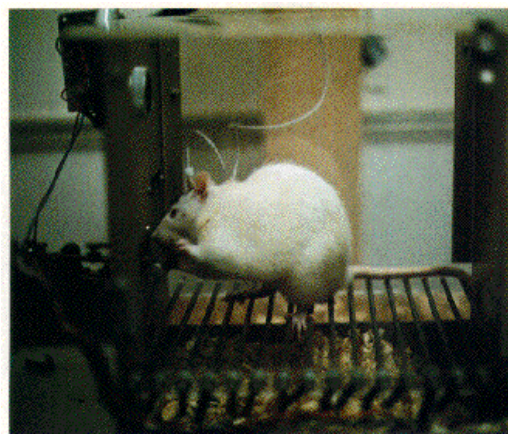
Drugs hijack the brain’s reward circuit

In addiction, craving becomes so powerful that it rules the addict’s life. This power results in part from changes to a specific path of neurons throughout the brain—the “pleasure system” or “reward circuit.” The reward circuit has been studied extensively in rodents. This is significant, since biochemical processes in these animals are strikingly similar to those of human beings.⁶

In a classic experimental design, researchers attach electrodes to points in the brains of living rodents—locations

that correspond to the reward circuit. When rodents press a special lever in their cages, a small electrical current travels via the electrodes directly to the animals’ reward circuit. Typically, some of the rodents press the lever compulsively—thousands of times, until they finally collapse in exhaustion.

Figure 8: Classic Rat Experiment and Drugs



These findings give a clue to the power of the reward circuit in human beings, which extends from the mid-brain to another section called the nucleus accumbens. This is where drugs of abuse create their effect by masquerading as natural chemicals. Steven Hyman, MD, director of the National Institute of Mental Health, described the action of drugs on this part of the brain in an interview with Bill Moyers (aired on public television as part of Moyers’ series on addiction titled *Moyers on Addiction: Close to Home*):

The nucleus accumbens seems to have a particular role in telling us what might be pleasing, what might be good for us . . . Cocaine and amphetamine put more dopamine in key synapses over a longer period of time in this brain

The Nature and Nurture of Addiction

*reward pathway than normal. And because they are so rewarding, because they tap right into a circuit that we have in our brains, whose job it is to say something like, "Yes, that was good. Let's do it again and let's remember exactly how we did it," people will take these drugs again and again and again.*⁷

For the person who uses chemicals to repeatedly stimulate the reward circuit, the prospect of abstaining from those chemicals can seem as hopeless and absurd as the idea of abstaining from food. An overpowering drive to drink or use other drugs compromises the user's will, changing what was once a voluntary behavior into an involuntary one.

Heredity influences response to drugs

Not all people who use drugs will experience the changes in brain structure and function described above. Some people can use drugs occasionally and remain occasional users. Other people, however, start using drugs casually and seem to progress inevitably to addiction. Researchers don't understand why this is so, but they know that heredity plays a role.

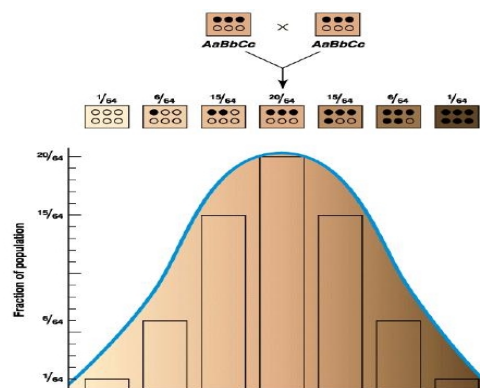
Each of us carries about 100,000 genes located in our cells on structures called chromosomes. And each gene directs the body to produce a specific protein (a process that's influenced by the action of neurotransmitters). The production of these proteins creates a chemical blueprint that shapes every

aspect of a human being, from height and weight to personality and behavior.

Unfortunately, the genetic blueprint is not fail safe; chance mutations in genes can produce hereditary diseases. A few of these—such as cystic fibrosis and Huntington's disease—result from a change in a single gene. Researchers have had some success in pinpointing the exact location of those genes and designing specific treatments in response.

In contrast, alcoholism and other forms of addiction result from changes in *many* genes. What's more, the genes that are involved can vary from person to person. These facts make the effort to locate the genes that influence addiction (gene markers) a task of overwhelming complexity. *[Editors note: The diagram below shows a poly genic distribution of the sort suspected in alcoholism].*

Figure 9: Poly Genic Gene Distribution



Still, we have abundant evidence that the predisposition to alcoholism is inherited. Identical twins born to alcoholic parents are more likely to become alcoholic than fraternal twins born to alcoholic parents. (Identical

The Nature and Nurture of Addiction

twins share identical genes; fraternal twins do not.) And, adopted children of alcoholic parents show higher rates of alcoholism than adopted children of non-alcoholic parents. This is true even when children of alcoholics are raised by non-alcoholic foster parents.

Figure 10: Twin Studies Show A High Genetic Factor in Drug Abuse



In a recent review article, Thomas McLellan, PhD, professor in the Department of Psychiatry at the University of Pennsylvania in Philadelphia, and his colleagues provide this summary of the relevant research: “Though there is need for more studies of heritability by drug and by gender, the evidence accumulated over the past several years suggests significant genetic contribution to the risk of addiction in approximately the same range as for chronic illnesses such as asthma and hypertension.”⁸

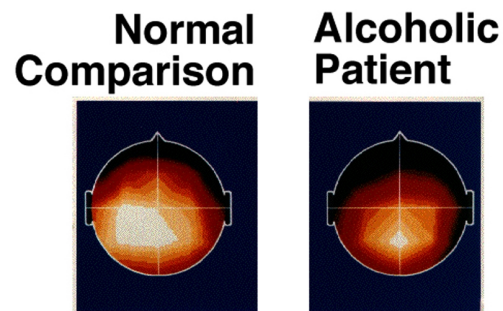
Brain waves may predict risk for addiction

A promising development in this area comes from studies by Henri Begleiter, MD, PhD, professor of psychiatry and neuroscience at the State

University of New York in Brooklyn, New York. While not able to identify precise gene markers for addiction, Begleiter has discovered another possible marker in the brain waves of people from alcoholic families.

Brain waves are recorded by a common medical device called an electroencephalograph and printed out as an electroencephalogram (EEG). When subjected to a significant sensory stimulus, such as a loud sound, most people respond with a common pattern: Between 300 and 500 milliseconds after the stimulus, their EEG shows a characteristic peak in brain waves. This part of the EEG is called the P3 amplitude. (The term *amplitude* refers to the height of the waves on the EEG.)

Figure 11: P300 Lead Example



In numerous studies that have been replicated by other researchers, Begleiter and colleagues discovered that the P3 amplitude tends to be lower in alcoholics—even those who have been abstinent for up to 10 years. In effect, people with this wave pattern often do not distinguish significant stimuli (those that are unique and unpredictable) from insignificant stimuli (those that are repeated and predictable). These people tend to process each sensory stimulus as

The Nature and Nurture of Addiction

new, a characteristic called *hyperexcitability*. This characteristic plays a key role in conduct disorders and other forms of impulsive behavior.⁹

The lowered P3 amplitude has another implication: It has been discovered in non-alcoholic relatives of alcoholics, including their children. This fact suggests that the unusual brain wave pattern is inherited, and that it may help predict people who are at risk to develop addiction. Begleiter suggests that people at risk for alcoholism inherit a general state of hyper-excitability, and that drinking alcohol relieves this state. Yet the relief is only temporary and depends on drinking increasing amounts of alcohol over time.¹⁰

Research has treatment applications

Begleiter believes that his findings have clear applications in treating and preventing addiction. “There are several approaches that may be implemented,” he says. One is “using behavioral and pharmacological means to reduce this hyper-excitability in young adolescents at risk to develop substance dependence. The other approach deals with prevention initiatives involving intense education starting at a very early age.”

Each of these strategies holds promise. For one, knowing the effects of addictive drugs on the brain holds the hope of developing medications to reduce craving. This has already been done with methadone for heroin addicts, naltrexone for alcoholics, and bupropion for nicotine addicts.

In addition, research can shape the way we educate people about addiction. “Research gives us information to use with patients and families in treatment to understand what has happened to them, why the addiction has occurred, and how it is not a matter of lack of will power,” says Patricia Owen, PhD, director of the Butler Center for Research at Hazelden. Also, people who know that they’ve inherited a risk for addiction can learn to abstain from alcohol and other drugs early on.

Equally important is placing people in treatment programs that reinforce changes in addictive behavior. To say that addiction involves biological factors does *not* mean that addicts are victims of biology. Indeed, the addict’s initial behavior—casual drug use—sets biological factors in motion. And, we can expect addicts to enter and comply with a treatment program.

Besides, it’s not only drugs that change the brain; stable changes in behavior can also alter brain function. For example, recovering alcoholics know that it’s wise to avoid the people, places, and things that they used to associate with drinking. This new behavior weakens the link between drinking and pleasure that’s been encoded in their brains.

Biology and behavior, then, must share the billing when it comes to explaining addiction and promoting recovery. According to the National Institute on Drug Abuse, the most effective treatment programs blend an array of strategies—medication, therapy,

The Nature and Nurture of Addiction

social services, rehabilitation, and self-help groups.¹¹

Leshner believes that these programs succeed because they treat the whole person. “Their treatment strategies place just as much emphasis on the unique social and behavioral aspects of drug addiction treatment and recovery as on the biological aspects. By doing so, they better enable those who have abused drugs to surmount the unexpected consequences of drug use and once again lead fruitful lives.”

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Wyoming: The First State to Apply the Science of Addictions

Some of the science discussed here is new; some is better known. State policy however has rarely been informed by comprehensive research. Generally policy has been set piecemeal. Wyoming is in the unique position of having commissioned a thorough review of the science as a foundation for designing policy. This entire document has focused on the review of the research on addictions—not from the perspective of what have we done wrong—but what could we as a state do right, even better than any other state in the Union.

Think of the use of good science in this plan in the same way that a good rancher; farmer or businessperson might do with the best information to maximize the productivity of the ranch, farm or business. Throughout much of Wyoming history, a Wyomingite might have used the good offices of an extension agent to get the best information available to make a good plan. We have done essentially the same in this plan. With a good understanding of the nature and nurture of substance abuse will mean that our state might be in a strong position to turn around the terrible epidemic that sprang up around during the past 15 years.

The Nature and Nurture of Addiction

How Plan Uses Science Of Substance Abuse

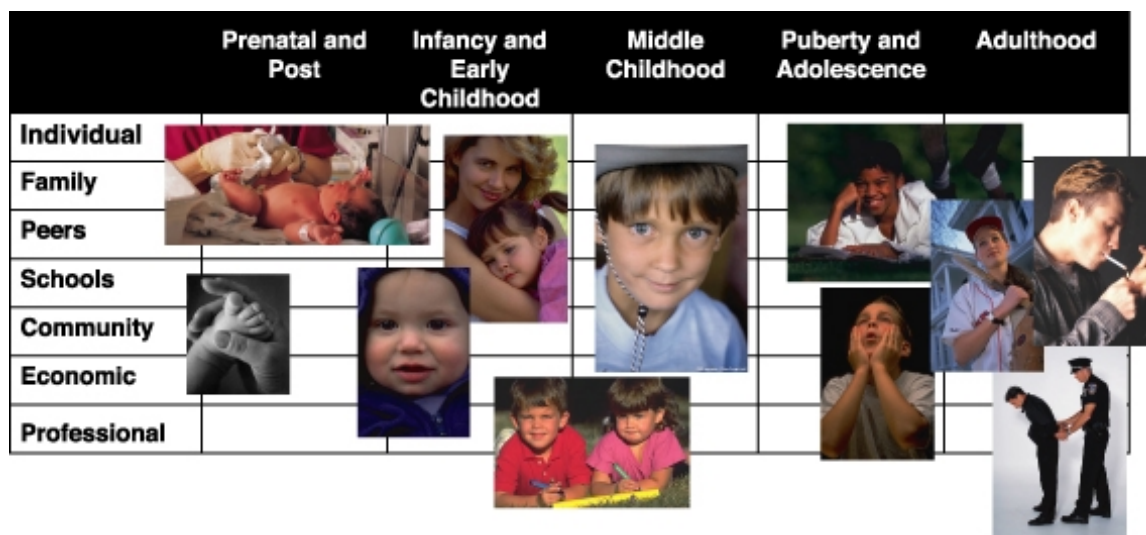
The next few pages highlight how this document integrates the science of treatment, intervention, prevention and control. Each section of the plan details more of the science, and some 10% of the entire report is composed of references to peer-reviewed scientific literature.

Brain and Medical Research

Human behavior becomes real through neural pathways. Just over 10 years ago, it was almost impossible to see and understand how the brain works. We are now making use of this emerging

exists that individuals with substance abuse problems are more sensitive to rewards (which is precisely one of the areas affected by most substances that people abuse or misuse).

- The treatment and data systems emphasize monitoring of the gene, drug, and treatment interactions since powerful science shows these interactions determine significant risk and protection.
- The prevention and intervention plan involving teens reflects the recent research on brain changes during adolescence, which helps explain why treating adolescents is so much more difficult and expensive than helping adults.



knowledge in several ways that bear enumeration, as examples:

- The early prevention components focus on affecting the inhibition circuits of the brain, since these have been strongly linked to elevated risk.
- The treatment and correctional interventions emphasize motivational enhancements, since clear evidence

Lifespan Research

Addicts do not just happen at age 24, 40 or whatever. Scientists now have fine-grained maps of developmental sequences that predict elevated risk for substance abuse that begin as early as conception and flow the old age. These pathways are critical for likely success,

The Nature and Nurture of Addiction

and help explain why so many well-intentioned strategies—even backed by much money—failed to produce the result desired.

The Wyoming Substance Abuse Blueprint covers the developmental lifespan issues, using significant scientific findings for all age groups. Figure 11 below provides a map of the lifespan orientation.

Behavioral Research

Substance abuse, misuse, and use involve behaviors. Almost 50 years of accumulated scientific results shows how to change behaviors effectively in many diverse contexts and age levels. Often, the strategies may not be well known, because they are largely the provinces of peer-reviewed scientific publications.

Certain infant behaviors and early mother behaviors predict either positive or adverse outcomes. Those behaviors can be changed, and this plan contains substantial evidence based practices to alter those patterns in both the child and parent.

Impulsivity and disruptiveness in boys during early childhood predicts substance abuse a decade later. Those behaviors can be changed, and this plan contains strongly backed scientific methods to change those behaviors.

Social withdrawal and early depression in girls elevates the risk of substance abuse later in life. This plan

contains research-based practices to address those behaviors.

Harsh, punishing, or overly permissive parenting styles of behavior elevate risk of substance abuse. This plan contains strong research based practices to address those behaviors effectively.

Teens and adolescents have a different pattern of risk taking behaviors that place them at elevated risk for substance abuse. This plan contains science-based strategies for addressing those behaviors.

Community adults engage in behaviors of giving substances to kids or making it easy for kids to obtain substances such as alcohol, tobacco, and other drugs. This plan holds out effective practices that change those adult behaviors.

How adults serve and interact with bar patrons' increases or decrease the risk of substance abuse in a community and increases or decreases the risk of murder, traffic fatalities and criminal assaults. This plan offers a number of well-proven strategies to improve those behaviors.

The choices that adults make can alter their risk for substance abuse. This plan offers any number of strategies emerging from good science on how to change those behaviors in a cost-effective way.

Good science shows that behavior change is possible, practical, and wise.

The Nature and Nurture of Addiction

Summary of Nature and Nurture

Well-controlled science shows that substance abuse, misuse, and use are the function of both nature and nurture, interacting in predictable ways. Human genetics and brain functions predict addictions. Certain social or behavioral contexts trigger those genetic or brain

effects. The Wyoming Substance Abuse Blueprint takes a balanced approach to understanding how the nature and nurture might be dealt with to reduce the problem of addictions and related multi-problem behaviors.

